WORLD VIEW

Biometric gonioscopy and the effects of age, race, and sex on the anterior chamber angle

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Aim: To utilise a novel method for making measurements in the anterior chamber in order to compare the anterior chamber angles of people of European, African, and east Asian descent aged 40 years and over.
Methods: A cross sectional study on 15 people of each sex from each decade from the 40s to the 70s, from each of three racial groups—black, white, and Chinese Singaporeans. Biometric gonioscopy (BG) utilises a slit lamp mounted reticule to make measurements from the apparent iris insertion to Schwalbe's line through a Goldmann one mirror goniolens. The main outcome measures were BG measurements of the anterior chamber angle as detailed above.
Results: There was no significant difference in angle measurement between black, white, and Chinese races in this study. However, at younger ages people of Chinese race appeared to have deeper angles than white or black people, whereas the angles of older Chinese were significantly narrower ($p = 0.004$ for the difference in slope of BG by age between Chinese and both black and white people).
Conclusion: The failure to detect a difference in angle measurements between these groups was surprising, given the much higher prevalence of angle closure among Chinese. It appears that the overall apparent similarity of BG means between Chinese and Western populations may mask very different trends with age. The apparently more rapid decline in angle width measurements with age among Chinese may be due to the higher prevalence of cataract or "creeping angle closure." However, longitudinal inferences from cross sectional data are problematic, and this may represent a cohort phenomenon caused by the increasing prevalence of myopia in the younger Singaporean population.

Glaucoma is estimated to be the second[1] or third[2] leading cause of blindness in the world. Primary open angle glaucoma (POAG) appears to comprise the large majority of these cases among European derived[3–5] and African derived[6] populations. However, primary angle closure glaucoma (PACG) appears to be a relatively common condition in east Asia,[7] and probably represents the majority of primary glaucomas among Chinese[8] and Mongolian[9] populations. The underlying reasons for these large differences in the epidemiology of glaucoma between Chinese and Western populations are not well understood. Some authors have found population differences in ocular biometry, with east Asian populations having shallower mean axial anterior chamber (AC) depth, a finding which might explain higher rates of PACG.[10] Other studies, using identical equipment and protocols to measure separate populations of black, white, and Chinese races, have failed to find significant differences in axial AC depth, axial length, or refractive error.[11]

The sine qua non in the clinical diagnosis and management of PACG has long been direct examination of the AC angle by means of gonioscopy. It is likely that precise measurement of the angle could add much to our understanding of the population epidemiology of PACG. Such studies are of more than academic interest. Because of the large populations of east Asia, PACG is clearly a major form of glaucoma worldwide.[1] The ability to measure the AC angle precisely and repeatably may not only help to better understand the epidemiology of the disease but also to screen for it more accurately.

We have recently reported on a new technique for measurement in the AC angle, biometric gonioscopy (BG).[12] Measurements made under our protocol were shown to correlate highly with conventional gonioscopy by an experienced observer, and also with digital Scheimpflug photography. The technique was also shown to be highly repeatable between observers and readily learnt by an individual with no previous ophthalmological training. We now report the results of a study in which BG measurements were made on defined populations of white, black, and Chinese races aged 40 years and above. The goal was to identify differences in direct measurement of the angle by age, race, or sex which might help to explain the variable prevalence of PACG in different racial groups, and which might not readily be detected by conventional axial measurements.

MATERIALS AND METHODS

Subjects

The study was designed to recruit 15 people of each sex in each decade from the 40s to the 70s and above, in each of three racial groups: white, black, and Chinese. The Chinese subjects were all drawn from an ongoing population based study in Singapore,[13] while black and white people were enrolled in medical emergency rooms and vision screening programmes in Philadelphia and Baltimore, USA. Age and a willingness and ability to participate were the only inclusion criteria. Exclusion criteria included bilateral pseudophakia or aphakia, previous incisional or laser glaucoma surgery, active ocular infection, recurrent erosion or other corneal surface abnormality in which gonioscopy might be contraindicated, media opacity precluding an adequate view of the AC angle, and any congenital or acquired condition likely to distort the anatomy of the angle (for example, Axenfeld-Rieger's anomaly, iritis leading to peripheral anterior synechiae).

Informed consent was obtained from all subjects, and the protocol was approved by the institutional review boards of the Wills Eye Hospital and the Johns Hopkins Hospital.

Table 1 Unadjusted mean biometric gonioscopy (BG) measurements (standard deviation in parentheses) by age and sex for the three racial groups—black, white, and Chinese races

Race	Age	BG mean (SD) for men	No of men	BG mean (SD) for women	No of women	Total
Chinese	40–49	4.42 (0.30)	15	4.57 (0.33)	15	30
	50–59	4.37 (0.31)	15	3.85 (0.40)	15	30
	60–69	4.03 (0.36)	15	2.84 (0.37)	19	34
	70–79	4.09 (0.33)	15	2.98 (0.38)	16	31
	Overall	4.23 (0.16)	60	3.51 (0.20)	65	125
Black	40–49	4.11 (0.26)	15	3.88 (0.19)	15	30
	50–59	3.57 (0.19)	15	4.05 (0.20)	16	31
	60–69	3.25 (0.28)	15	3.47 (0.26)	15	30
	70–79	3.65 (0.25)	11	3.74 (0.21)	20	31
	Overall	3.64 (0.13)	56	3.79 (0.11)	66	122
White	40–49	3.72 (0.24)	15	4.01 (0.29)	19	34
	50–59	4.56 (0.45)	9	3.89 (0.29)	16	25
	60–69	3.39 (0.43)	7	3.56 (0.33)	17	24
	70–79	4.07 (0.33)	15	3.51 (0.25)	17	32
	Overall	3.95 (0.18)	46	3.75 (0.15)	69	115
Total			162		200	362

Protocol for biometric gonioscopy

All measurements in Singapore were made by a single investigator (PJF), as were those in Baltimore and Philadelphia (NGC). An identical one mirror Goldmann mirror (Charles Bell Instruments, Westville, NJ, USA) was used with a Haag-Streit 900 slit lamp (a BM model in the United States and a BQ in Singapore) equipped with a Haag-Streit measuring eyepiece (Haag-Streit AG, Liebefeld-Berne, Switzerland). The two main investigators (NGC, PJF) were previously standardised against one another by examining patients of varying AC depth in a glaucoma specialty clinic. The purpose of utilising this population was to allow standardisation without providing either investigator with a priori knowledge as to the expected range of "normal" measurements in a population. After initial standardisation, 15 eyes of 15 subjects were examined by the two investigators, with the mean biometric grade for the four quadrants of each examined eye differing by no more than one unit between investigators (data not shown).

The protocol for BG has been described in detail elsewhere,[12] and is reviewed here in outline form. All measurements were made in the left eye, unless the left eye met exclusion criteria, in which case the right eye was used. Conditions were standardised as follows: ambient light from a small indirect source, total magnification of 16× and a power of 6 W, using the middle filter setting and a slit beam size of 4 × 1 mm. No attempt was made to standardise the subject's direction of gaze, angle of the slit beam, or placement of the goniolens on the eye; these were allowed to vary so as to maximise the measurement in each quadrant.

Measurements were made from the first point of contact between iris and the eye wall (that is, the apparent iris insertion) to Schwalbe's line, using the reticule in the measuring eyepiece. Although the eyepiece is calibrated in millimetres, as a result of the magnifying effect of the slit lamp and goniolens optics, all BG measurements are expressed in arbitrary units. Each quadrant was measured separately, with the average being recorded as the grade for a given individual. In the case of a completely closed quadrant, a measurement of 0 was recorded.

Statistical procedures

Mean measurement for each quadrant was compared with the overall mean for all quadrants. This was carried out for all subjects and within the racial groups, using the *t* test with Bonferroni correction. A regression model was fitted with a mean BG measurement for the eye as an outcome and with age, race, and sex as explanatory variables. Regression interaction terms were used to compare the slopes of BG measurement by age for different racial and sex groups.

RESULTS

Recruitment was complete for all age and sex groups in all races, with the exception of white males in their 70s and black males in their 50s and 60s (Table 1).

When mean BG grades for the four quadrants were compared, the mean for the superior quadrant (3.11 (SD 1.37)) was significantly lower than the mean for each of the other three quadrants ($p < 0.0001$ for each, *t* test with Bonferroni correction). The mean for the inferior quadrant (4.30 (1.45)) was significantly higher than the mean for each of the other three quadrants ($p < 0.0001$ for each, *t* test with Bonferroni correction). Neither the mean for the nasal (3.91 (1.33)) nor the temporal (3.87 (1.36)) quadrant differed significantly from one another ($p > 0.20$ for both). This pattern was the same for all three racial groups (Fig 1).

The mean BG measurement for black (3.83 (SD 0.16)), white (3.72 (0.12)), and Chinese people (3.85 (0.18)) did not differ significantly from one another (Table 1). There were also no significant differences in BG measurement by race when a regression model was used to adjust for age and sex. In this model, older age and female sex were both associated with narrower BG angle measurements (Table 2).

Although the BG mean did not differ by race, analysis by age (Fig 2) shows that the mean for younger Chinese is above that of black and white people, while that of older Chinese is somewhat less. The slope of the BG by age line for Chinese subjects is significantly steeper than for black people ($p = 0.004$, regression interaction term) or white people ($p = 0.004$). This apparent steeper decline was due almost entirely to a significantly steeper slope of the BG by age line for Chinese women compared to men (Fig 3) ($p = 0.006$, regression interaction term). Sex differences were not significant for black and white people. The majority of the lowest BG measurements in the study were for older Chinese women (Fig 3).

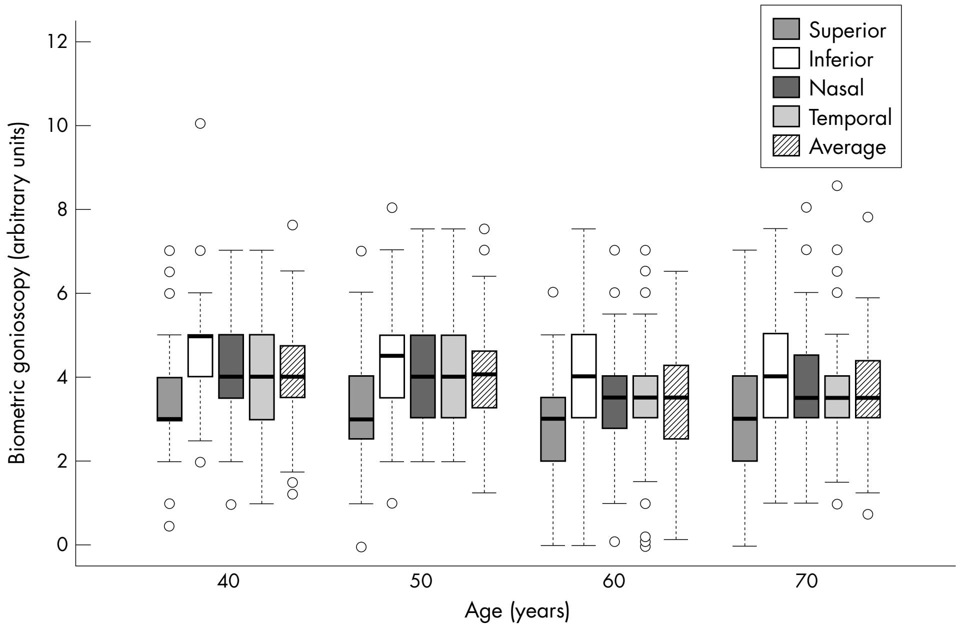

Figure 1 Mean grade for each of the four quadrants by age (data for all racial groups pooled).

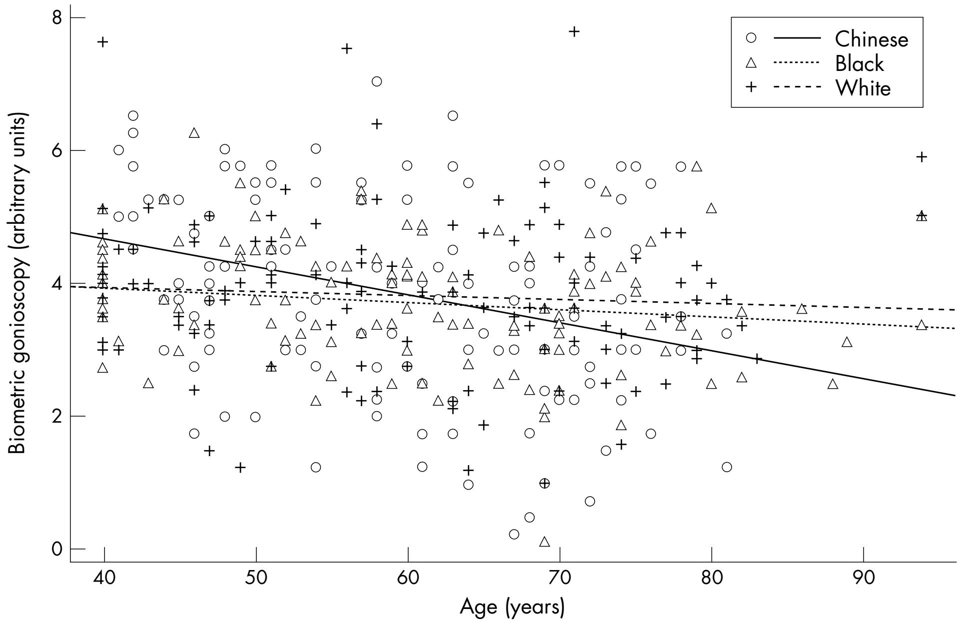

Figure 2 Biometric measurement by age for the three racial groups—black, white, and Chinese races.

Table 2 Regression model for the effects of age, sex, and race (independent variables) on biometric gonioscopic grade (dependent variable). Older age and female sex are significantly associated with a more narrow angle grade

Independent variable	β Coefficient	Standard error	p Value
Age (per year)	–0.017	0.005	0.001
Female sex	0.251	0.128	0.050
Chinese race (compared to white)	0.121	0.154	0.433
Black race (compared to white)	0.112	0.138	0.418

DISCUSSION

Many of the basic results of this study are in accord with clinical experience and previous studies. Though the reasons are not well understood, the superior quadrant is well known to be the narrowest gonioscopically, and the inferior the deepest, both of which are in accord with our results. The tendency that we found for narrower angles with ageing has been thoroughly documented in the past for white people,[14–16] Inuit,[17 18] Chinese,[8 19] and Japanese races.[20] Likewise, our finding of narrower angles among women is well known for white people,[14 16] Eskimos,[17] and Asians.[8 9 20 21] Narrowing of the angle with age has generally been thought to be due to thickening and slight anterior movement of the lens throughout life,[22 23] while narrower angles among women seem to be associated simply with a smaller overall ocular[11] and general body size.

In view of the markedly higher prevalence of PACG among Chinese compared with black and white people,[7] it is surprising that angle measurements did not differ significantly

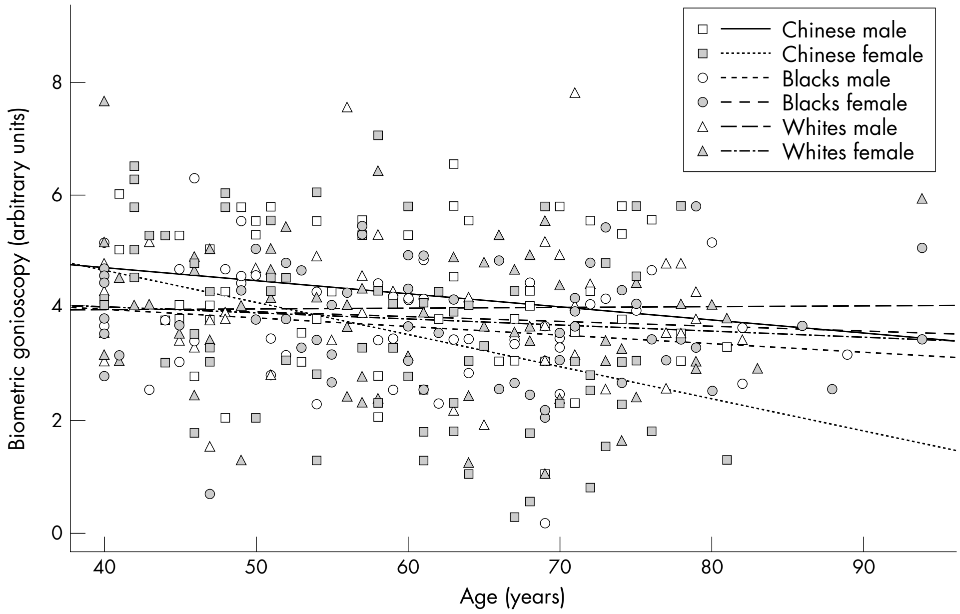

Figure 3 Biometric measurements by age and sex for the three racial groups—black, white, and Chinese races.

between racial groups. However, it appears that the overall similarity of means between races masks rather prominent differences in BG trends by age. Younger Chinese subjects appeared to have deeper angles than Western subjects, while older Chinese, especially women, had significantly narrower angles, with the difference in the BG slope by age differing significantly between the races. Possible mechanisms that could explain the preponderance of narrower angles among older Chinese include a higher prevalence of unoperated cataract compared with the United States (though recent studies would suggest that rates of cataract surgery among Chinese Singaporeans are quite similar to those in the United States[24]), or the anecdotal phenomenon of "creeping angle closure," which has been described but never documented among Chinese populations.[25–27]

Although it may be acceptable in some circumstances to draw longitudinal inferences from cross sectional data, this must be done with caution, and is based on several assumptions. The most important of these is that conditions affecting the outcome of interest have not changed significantly over time. Temporal change which violates this assumption is called a "cohort effect." In fact, the apparently more rapid decline in angle measurement for Chinese in this study may be an artefact of just such a cohort effect. It has been reported[28–30] that rates of myopia among Chinese are increasing rapidly, particularly in areas such as Singapore and Hong Kong where educational opportunities are available to a large proportion of the population. The increase in myopia may also be associated with an increase in the axial parameters of the eye,[28 29] which could in turn be associated with deepening of the AC angle.

If these educational opportunities or other factors leading to increased rates of myopia have only recently come into play for the population tested in Singapore, it is possible that younger individuals in their 40s actually have deeper angles as a result, while the older cohort in their 60s and 70s, who were never exposed to such influences, remain in their natural condition with narrow angles. Recent studies in Singapore have in fact documented higher rates of myopia and deeper mean anterior chamber depth among subjects aged 40–49 years compared to older people.[31] The apparently more rapid decline in angle measurements with age could thus be an artefact of the cross sectional design of our study. When individuals in the current younger cohort move into their 60s and 70s, they might be expected to have deeper angles than the older cohort currently alive.

The distinction between a real phenomenon of more rapid narrowing of the angle among Chinese and an artefactual cohort effect is of more than theoretical interest. If the phenomenon is real, it would provide another argument in favour of focusing preventive resources for PACG on older people in this population. Further research into the phenomenon would also be warranted, and might offer significant insights into the mechanisms underlying angle closure. If our results are due to a cohort effect, they would be among the first evidence that increased rates of myopia are in fact decreasing the risk for PACG in Chinese populations, and might suggest that this condition will become less of a public health problem in the future. The matter can only be settled definitively by long term prospective studies of ocular biometry in Chinese populations, or by studies in remote areas where the social or other factors underlying increased rates of myopia are clearly not present.

In addition to the limitations imposed by its cross sectional design, other limitations of the study must be acknowledged. While Chinese subjects were recruited on a population basis in Singapore as part of a larger study,[32] white and black subjects were drawn from medical emergency rooms in the eastern United States. The greatest concern in comparing groups recruited differently is that the results will be subject to bias, whereby the groups differ systematically along some parameter other than that for which the comparison is being made—namely, race. Such bias cannot be excluded in this case. However, the factors which are known to influence anterior chamber biometry are relatively few: age, sex, refractive error, stature.[33] There is no particular reason to think that people presenting to a medical emergency room would tend to differ systematically from the general population with regard to refractive error or stature, and age and sex were controlled for by sampling an equal number of subjects of each sex and decade in each of the racial groups.

A second limitation is that the examinations and BG measurements were carried out by different investigators in Singapore and in the United States. As noted in the Methods section, however, the two observers were standardised against one another at the outset of the study. Further, the interobserver reliability of BG measurements has been shown to be good in previous studies.[12] None the less, the possibility cannot be excluded that the observed differences between Chinese, black, and white subjects were due in part to different observers.

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